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DØ

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ABSTRACT

A preliminary differential cross section $d^2\sigma/dp_T d\eta$ for the inclusive production of direct photons, $\bar{p}p \longrightarrow \gamma + X$, at $\sqrt{s} = 1.8$ TeV is presented. Photon candidate events included in the cross section are in the transverse momentum range $14 < p_T < 90$ GeV/c and the pseudorapidity range $-0.9 < \eta < 0.9$. The estimate of the background in the photon candidate sample due to multi-photon sources is discussed. The data are compared with recent next-to-leading-order predictions.

1. Introduction

During the past 15 years, experiments studying direct photon production in hadron collisions have confirmed the utility of this process as a test of QCD and a means to constrain some of its parameters. Experiments have been performed in a wide range of kinematic regimes with different projectile and target particles, and qualitative agreement has been seen between the data and next-to-leading-order (NLO) perturbative QCD predictions[1]. Current efforts[2] focus on using direct photon data to constrain the gluon structure function in nucleons, since the sensitivity to the gluon distribution is much greater for direct photon production than for deep inelastic lepton scattering, the process mainly used to determine parton distributions.

The DØ Experiment at the Fermilab Tevatron Collider will attempt to constrain the gluon distribution at low Bjorken-x by studying the pseudorapidity (η) distribution of photons produced at low p_T. Different gluon shapes used as inputs to the NLO calculations yield different predicted η distributions[3]. These differences are greatest for $p_T \approx 10$ GeV/c, so DØ will concentrate on the detection of photons at low p_T throughout the entire η range. Several features of the DØ calorimeter[4,5] are well-suited for direct photon detection: good electromagnetic (e.m.) energy resolution, uniformity, fine transverse granularity, 4-fold longitudinal depth segmentation, and coverage in η extending to ± 4.2.

We present here a preliminary differential cross section $d^2\sigma/dp_T d\eta$ for inclusive direct photon production based on an integrated luminosity of 130 nb^{-1}, restricted to the central region $-0.9 < \eta < 0.9$ and the photon transverse momentum range $14 < p_T < 90$ GeV/c.

2. Trigger and Event Selection

Direct photon candidates derive from triggers which select events with localized, isolated energy deposition in the e.m. calorimeter. Triggers with different p_T thresholds are used in order to populate the rapidly-falling photon p_T spectrum with good statistics throughout the range. Level-1 e.m. triggers are based on towers of size $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$. Photon candidates for this analysis stem from triggers with Level-1 E_T thresholds of 7 GeV, which are prescaled by a factor ranging from 50 to 200 (depending on the instantaneous luminosity), and 14 GeV, which are not prescaled. The Level-1 thresholds of 7 and 14 GeV are filtered in Level-2 with E_T thresholds of 8 and 30 GeV, respectively. Candidate events are further filtered in Level-2 with requirements that the e.m. clusters have longitudinal and transverse development consistent with electrons measured in test-beam studies. In Level-2, photon candidates are also required to be isolated in a cone of size $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.4$ centered on the candidate cluster, which means that the total (e.m. + hadronic) energy in the cone is at most 15% greater than the energy of the candidate e.m. cluster.

Offline selection of photon candidates closely follows the trigger criteria. Candidates are required to have <10% of their energy in the hadronic sector of the calorimeter, to be narrow in the transverse direction, and to be isolated in a cone $\Delta R = 0.4$. In addition, no charged track is allowed to point toward the photon candidate within a region $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$.

3. Background Estimation

The sample of direct photon candidates contains a significant background, primarily due to the two-photon decays of π^0's which frequently are the leading particles in jets. In most cases, the granularity of the DØ detector is not sufficiently fine to distinguish two π^0 photons from a single, direct photon. We have estimated the background fraction using the Conversion Method[1]. This method relies on the fact that background π^0's are approximately twice as likely to yield a conversion to an e^+e^- pair in the material before the DØ central drift chambers (CDC) and the calorimeter compared to single, direct photons. The absence of a central magnetic field in DØ causes conversion pairs to remain collinear, giving a track pulse height equivalent to 2 minimum ionizing particles (mip), as measured by the CDC.

A "conversion sample" of photon candidates consists of e.m. clusters which satisfy the same trigger and offline selection criteria as the main photon candidate sample, with the additional requirement that the events have a track pointing to the candidate cluster with a measured dE/dx consistent with 2 mip. Fig. 1 is an example of a track dE/dx distribution from which the number of events in the conversion sample is extracted. Clear 1 mip and 2 mip peaks are visible, and the curve represents a combined Landau-like fit to the two peaks.

The main photon candidate sample and the conversion sample contain different mixtures of the direct photon signal and the π^0 background. Each mixture is determined by the probability, p, for a single photon to convert and yield a 2 mip track in the CDC. This probability has been estimated to be $p = 12\pm2\%$, based on Monte Carlo simulation. The fraction of direct photons in the photon candidate sample is derived by comparing the above two samples and is estimated to be $42\pm14\%$; the error is statistical. Our estimation of the background contribution to the photon candidate sample will be refined in future analyses to include the dependence on photon p_T, consideration of other multi-photon backgrounds (η's, ω's, K^0's), and the effect of tracking inefficiencies on the photon and conversion samples. Both the statistical and systematic uncertainties in the background estimation via the Conversion Method will improve with higher statistics. Independent techniques for estimating the background, based on detailed studies of shower longitudinal development and the isolation criteria, are also being employed.

4. Differential Cross Section

Fig. 2 shows the differential cross section $d^2\sigma/dp_T d\eta$ vs. p_T for inclusive direct photon production in the pseudorapidity range $-0.9 < \eta < 0.9$. Data points shown with open squares derive from the Level-2 $p_T > 8$ GeV/c trigger threshold, and darkened squares are from the Level-2 $p_T > 30$ GeV/c threshold. The error bars represent statistical and estimated systematic uncertainties combined in quadrature. The main contributions to the systematic errors are from our estimated uncertainties in the luminosity measurement (15%), the p_T scale (25%), and the background subtraction (50%). Fig. 2 also shows the predicted cross section from a recent NLO calculation[6] performed for the same kinematic range, using similar photon isolation criteria at the parton level. The input structure functions, MRS[7] Set D_0, are derived from fits to experimental data that include recent NMC data and CCFR data at small x. The solid curve uses a q^2 scale defined by $\mu = p_T$, and the dashed curve uses $\mu = p_T/2$. Good qualitative agreement is seen between this preliminary cross section and the theoretical predictions. These results encourage us to extend the measurement of direct photon production at DØ to lower p_T values throughout the entire pseudorapidity range.

5. Acknowledgements

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6. References

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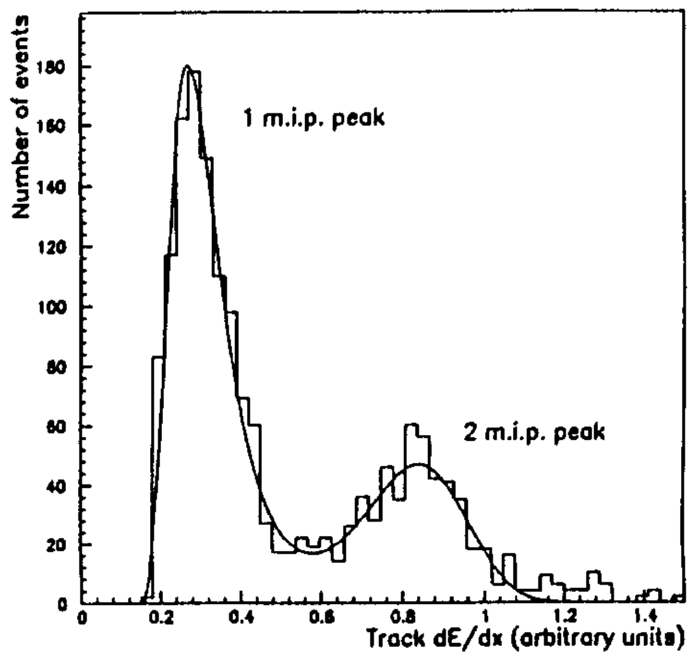

Fig. 1. A dE/dx distribution for photon candidates with an associated track, as measured by the Central Drift Chambers.

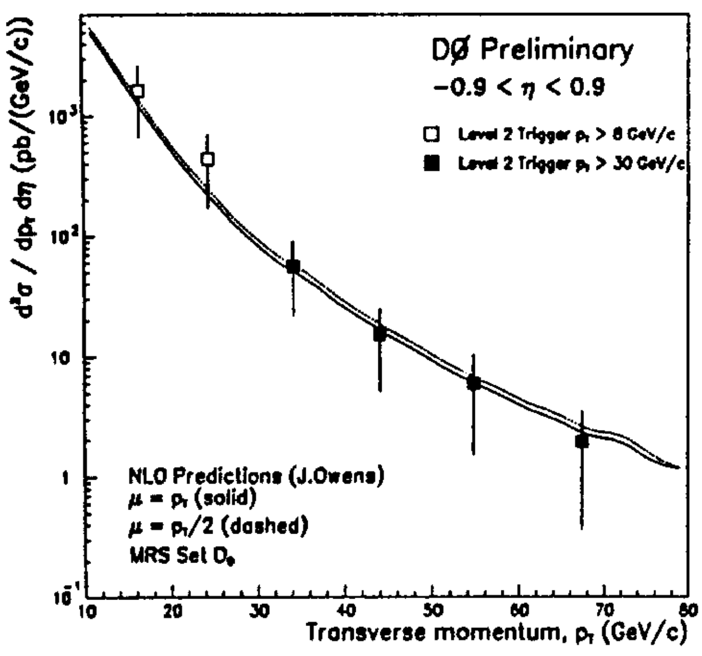

Fig. 2. Differential cross section for inclusive direct photon production, $\bar{p}p \longrightarrow \gamma + X$, vs. photon p_T at $\sqrt{s} = 1.8$ TeV with comparison to next-to-leading-order theoretical predictions.